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SYSTEMATIC ERRORS IN RIVER DISCHARGE MEASUREMENTS

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SYSTEMATIC ERRORS IN RIVER DISCHARGE MEASUREMENTS

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EXECUTIVE SUMMARY

The primary principle of the Water Resources Branch is the collection of high quality water resources data to satisfy the ever increasing demand of the water resource community. In keeping with this principle the Water Resources Branch is continuously assessing its procedures and standards in light of advancements in technologies and knowledge. This report is only one of the steps in the continued search for excellence by the Branch.

The evaluation summarized in this report is a cursory look at the elements which affect the measurement of river discharge in typical prairie streams. It concludes that errors in discharge measurements can be significant for river discharges of 0.01 m^3/s but these errors quickly decrease to less than 5% for river discharges greater than 0.1 m^3/s. The report also concludes that the greatest source of error is in measuring depth of water.

R.G. Boals

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SYSTEMATIC ERRORS IN RIVER DISCHARGE MEASUREMENTS

PURPOSE:

The purpose of this report is to evaluate the sensitivity of river discharge measurements to systematic errors in measuring depth, cross-sectional width, and current meter revolutions in a fixed interval.

APPROACH:

Five previously computed discharge measurements were selected for the following flow ranges:

a) 0.010 m^3/s
b) 0.100 m^3/s
c) 1.00 m^3/s
d) 5.00 m^3/s
e) 10.0 m^3/s

These discharges were chosen carefully and are considered to be "good measurements". The actual discharges used are as close as possible to the selected values listed above.

New discharge values were then calculated introducing the following conditions or errors.

a) The depth of each vertical is increased by 0.02 metres.
b) The cross section width is skewed ten degrees from perpendicular.
c) The number of revolutions is decreased by two.
d) The depth of each vertical is increased by 0.02 metres, cross section width is skewed ten degrees from perpendicular, and the number of revolutions is decreased by two.

The new discharge values were used to calculate the absolute error. The absolute error is equal to the following formula:

$$\text{ABSOLUTE ERRROR} = |\text{DISCHARGE BEFORE} - \text{DISCHARGE AFTER}|$$

Using these new values the percent errors were calculated using the following formula.

$$\text{PERCENT ERROR} = \frac{|\text{DISCHARGE BEFORE} - \text{DISCHARGE AFTER}|}{\text{DISCHARGE BEFORE}} * 100\%$$

A percent error was calculated for each discharge with each condition implemented.(See Tables 1-4) A plot of the percent error as a function of discharge was then drawn,using Harvard Graphics. (See figure 1)

ERRORS IN DISCHARGE MEASUREMENTS

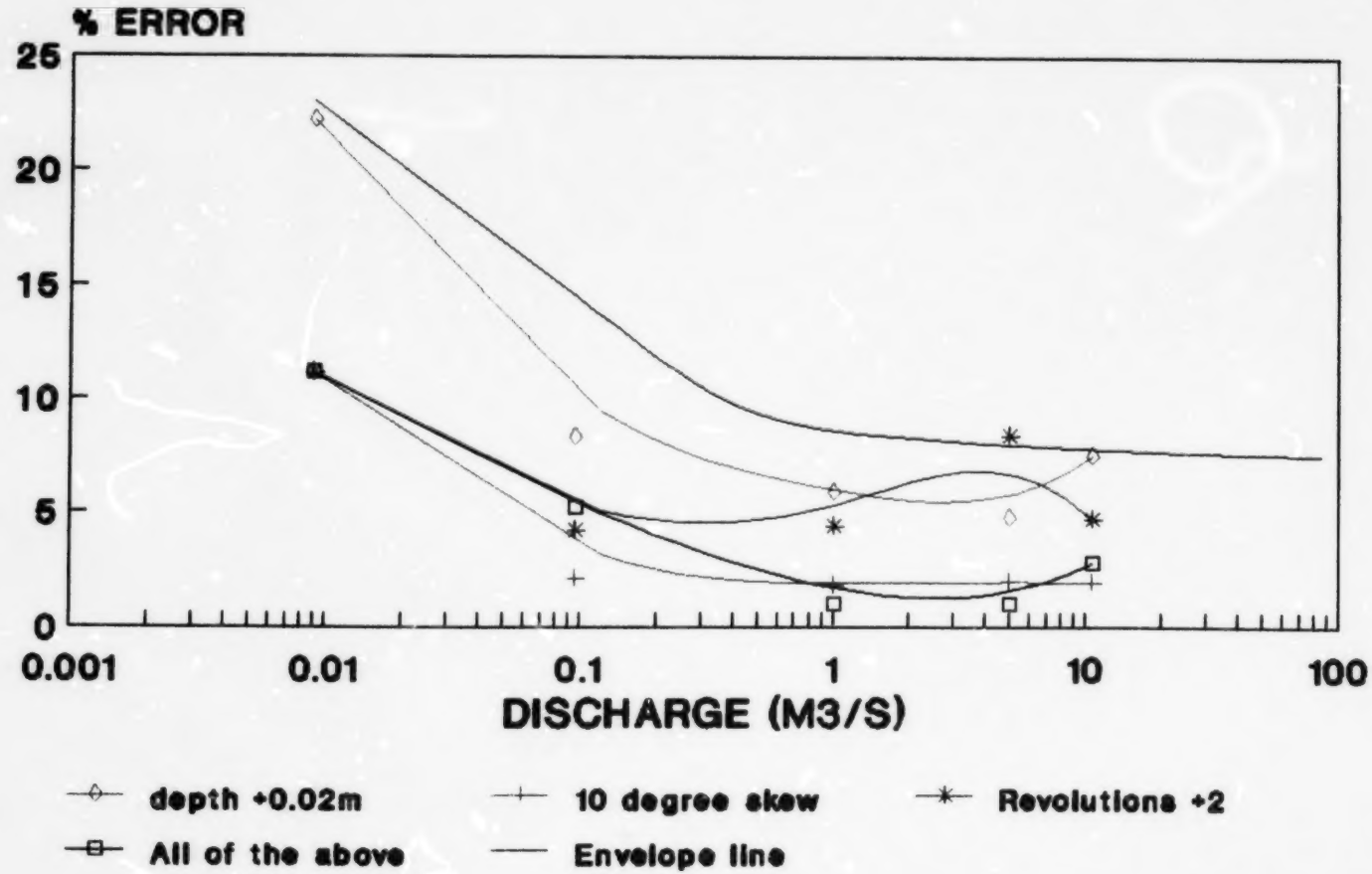

Figure 1

DISCUSSION:

From the graph, it can be determined that the greatest source of error arises from inaccurate measurements in the depth of the channel. This is particularly prevalent at low flows. For example, the error at 0.009 m^3/s is 22.2%.

There seems to be a trend, that errors introduced in the low flows measurements have a dramatic effect on the discharge. Consequently, it is very important to be especially careful when taking measurements at low flows. Because the error is so significant estimating the discharge by eye should be avoided. Metering should be done if at all possible. If an estimate must be used, care should be taken to ensure that it is a good estimate. This may involve measuring the depth and width of the channel with a wading rod in order to calculate a reasonably accurate area.

Errors in discharge resulting from skew, that is when the flow is not perpendicular to the cross section, appear to be very low. This is interesting because a great deal time is spent in the field trying to ensure that the cross section is perpendicular to the flow. This does not mean that the effort should not be made, but rather that the same degree of effort should be made trying to eliminate other conditions such as errors in depth, which result in a much larger error in the discharge.

From the graph it can be seen that each condition has a different affect on the discharge, with depth having the greatest error for most discharges. Other conditions, such as the combined errors of depth, cross section, and revolutions have a remarkably low percent error. This condition probably arises because the error conditions act in opposite directions, negating the effects of each individual condition.

It is worth noting that the magnitude and order of the percent error for each type of error fluctuates as flow volume changes. For example, at a discharge of 0.009 m^3/s the percent errors are as follows:

Depth	22.2%
Revolutions	11.1%
Skew	11.1%
All of the above	11.1%

However, at a discharge of 0.096 m^3/s the magnitude has decreased significantly to the following :

Depth	8.3%
All of the above	5.2%
Revolutions	4.2%
Skew	2.1%

From this it can be determined that the percentage of error for a certain error condition does not remain the same, but affects each measurement, probably each vertical in a different manner.

Because of these uncertainities, care should be taken to choose a good cross section. Try to choose one which is perpendicular to the flow and has a channel bed which is free of large rocks. If these types of conditions are avoided, and care is taken while performing the measurement, a significant amount of error will be eliminated from the discharge measurement.

CONCLUSIONS:

1) Discharge measurements are more sensitive to systematic errors at low flow than discharge measurements at high flow.

2) Intermediate flow rates are affected differently, by the same condition. For example, a certain condition may increase the discharge at 0.100 m^3/s and decrease it at 1.00 m^3/s.

3) The discharge is affected to the greatest extent by errors in determining the depth.

4) The combined affects of errors in depth, cross-section width, and the number of revolutions, results in a very low percent error.

RECOMMENDATIONS:

1) The discharge of a stream should not be estimated, but should instead be metered. If it is not possible, then some necessary information must be measured.

2) Care should be taken in choosing the site for the measurement. Sites should be chosen where the flow is perpendicular to the cross section and free of reverse flows. Also, a site should be located where the stream bed is free of large rocks that can interfere with metering.

3) Accurate readings of the depth and accurate counting of revolutions is vital. If care is taken in collecting these two parameters then a significant percentage of the error can be avoided.

4) Some investigation into the adaption of the Current Meter Digitizer currently used by the United States Geological Survey for use in Canada should be carried out.

TABLE # 1

ERROR: The depth of each vertical is increased by 0.02 metres

STATION	DISCHARGE BEFORE ERROR (m^3/s)	DISCHARGE AFTER ERROR (m^3s)	ABSOLUTE ERROR (m^3s)	% ERROR
Hay Meadow Creek near Lisieux 11AE010	0.009	0.011	0.002	22.2%
Girard Creek near Coronach 11AE015	0.096	0.104	0.008	8.3%
Qu'Appelle River near Lumsden 05JF001	1.01	1.07	0.060	5.9%
Qu'Appelle River below Loon Creek 05JK007	4.99	5.23	0.240	4.8%
Qu'Appelle River below Moose Jaw River 05JG007	10.6	11.3	0.800	7.5%

TABLE # 2

ERROR: Cross-section width is skewed 10 degrees from perpendicular

STATION	DISCHARGE BEFORE ERROR (m^3/s)	DISCHARGE AFTER ERROR (m^3/s)	ABSOLUTE ERROR (m^3/s)	% ERROR
Hay Meadow Creek near Lisieux 11AE010	0.009	0.008	0.001	11.1%
Girard Creek near Coronach 11AE015	0.096	0.094	0.002	2.1%
Qu'Appelle River near Lumsden 05JF001	1.01	0.992	0.018	1.8%
Qu'Appelle River below Loon Creek 05JK007	4.99	4.89	0.100	2.0%
Qu'Appelle River below Moose Jaw River 05JG007	10.6	10.4	0.200	1.9%

TABLE # 3

ERROR: The number of revolutions is decreased by 2

STATION	DISCHARGE BEFORE ERROR (m^3/s)	DISCHARGE AFTER ERROR (m^3/s)	ABSOLUTE ERROR (m^3/s)	% ERROR
Hay Meadow Creek near Lisieux 11AE010	0.009	0.008	0.001	12.5%
Girard Creek near Coronach 11AE015	0.096	0.092	0.004	4.2%
Qu'Appelle River near Lumsden 05JF001	1.01	0.966	0.044	4.6%
Qu'Appelle River below Loon Creek 05JK007	4.99	4.57	0.042	8.4%
Qu'Appelle River below Moose Jaw River 05JG007	10.6	10.1	0.50	4.7%

TABLE # 4

ERROR:The depth of each vertical is increased by 0.02 metres,cross-section width is skewed 10 degrees from perpendicular and the number of revolutions is decreased by 2

STATION	DISCHARGE BEFORE ERROR (m^3/s)	DISCHARGE AFTER ERROR (m^3/s)	ABSOLUTE ERROR (m^3/s)	% ERROR
Hay Meadow Creek near Lisieux 11AE010	0.009	0.010	0.001	11.1%
Girard Creek near Coronach 11AE015	0.096	0.101	0.005	5.2%
Qu'Appelle River near Lumsden 05JF001	1.01	1.00	0.010	1.0%
Qu'Appelle River below Loon Creek 05JK007	4.99	4.94	0.050	1.0%
Qu'Appelle River below Moose Jaw River 05JG007	10.6	10.3	0.300	2.8%

TABLE # 5

STATION	DISCHARGE (m^3/s)	AREA (m^2)	WIDTH (m)	MEAN VELOCITY (m/s)
Hay Meadow Creek near Lisieux 11AE010	0.009	0.08	1.2	0.112
Girard Creek near Coronach 11AE015	0.096	0.279	1.9	0.344
Qu'Appelle River near Lumsden 05JF001	1.01	1.91	6.5	0.529
Qu'Appelle River below Loon Creek 05JK007	4.99	8.46	17.8	0.590
Qu'Appelle River below Moose Jaw River 05JG007	10.6	18.8	14.0	0.564

NOTE: All data from original front sheets.